

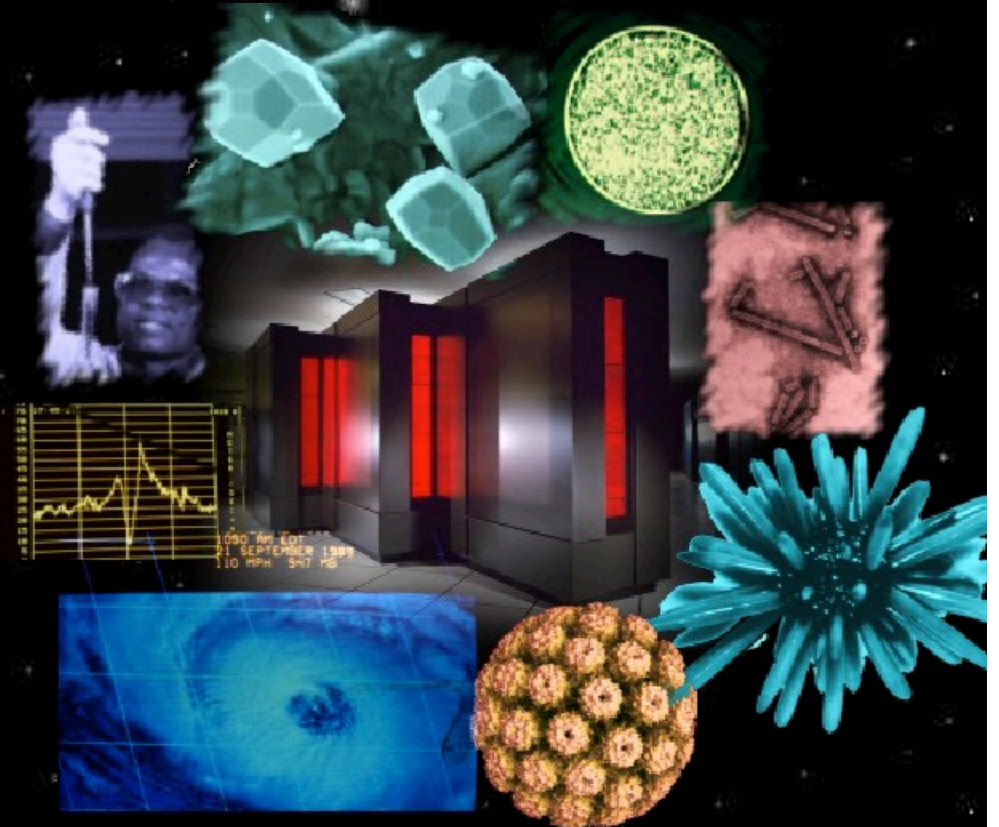


The Scientific Revolution

From Aristotle to Einstein

Discoveries & Achievements

- The Scientific Revolution began in the middle decades of the 16th century and continued through the early part of the 18th century. It involved gradual developments in astronomy, physics, chemistry, and biology.



Astronomy: A New Model of the Universe

- The major change in astronomy was that people accepted the theory proposed by Nicolaus Copernicus' (1473-1543) that the sun rather than the earth was the center of the universe.



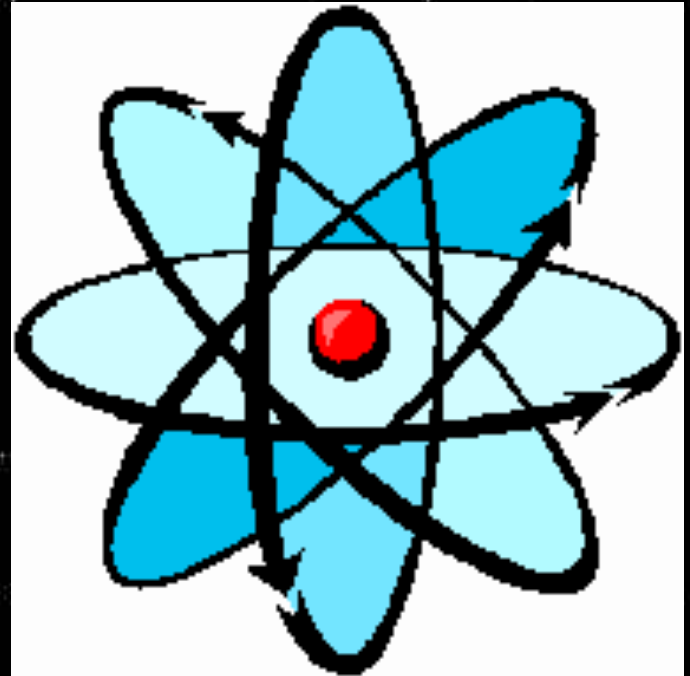
Physics: Laws of Motion and Gravitation

- The most important contributions in physics were the theory of inertia, proposed by Galileo (1564-1642), and the force of gravity discovered by Sir Isaac Newton (1642-1727).



Chemistry: The Discovery of Elements of Nature

- The Englishman Robert Boyle (1627-1691) made chemistry respectable by his discovery that the arrangement of atoms determines the characteristics of matter. Previously, it had been associated with alchemy.

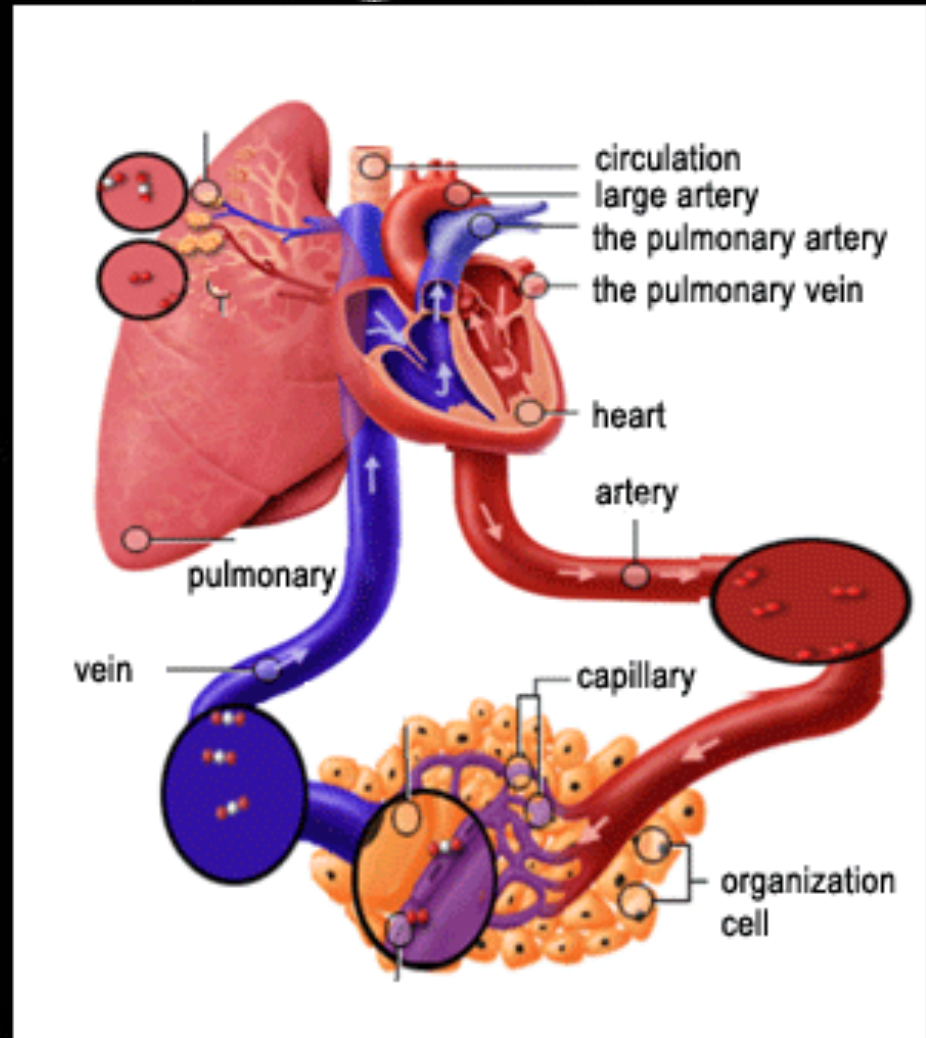


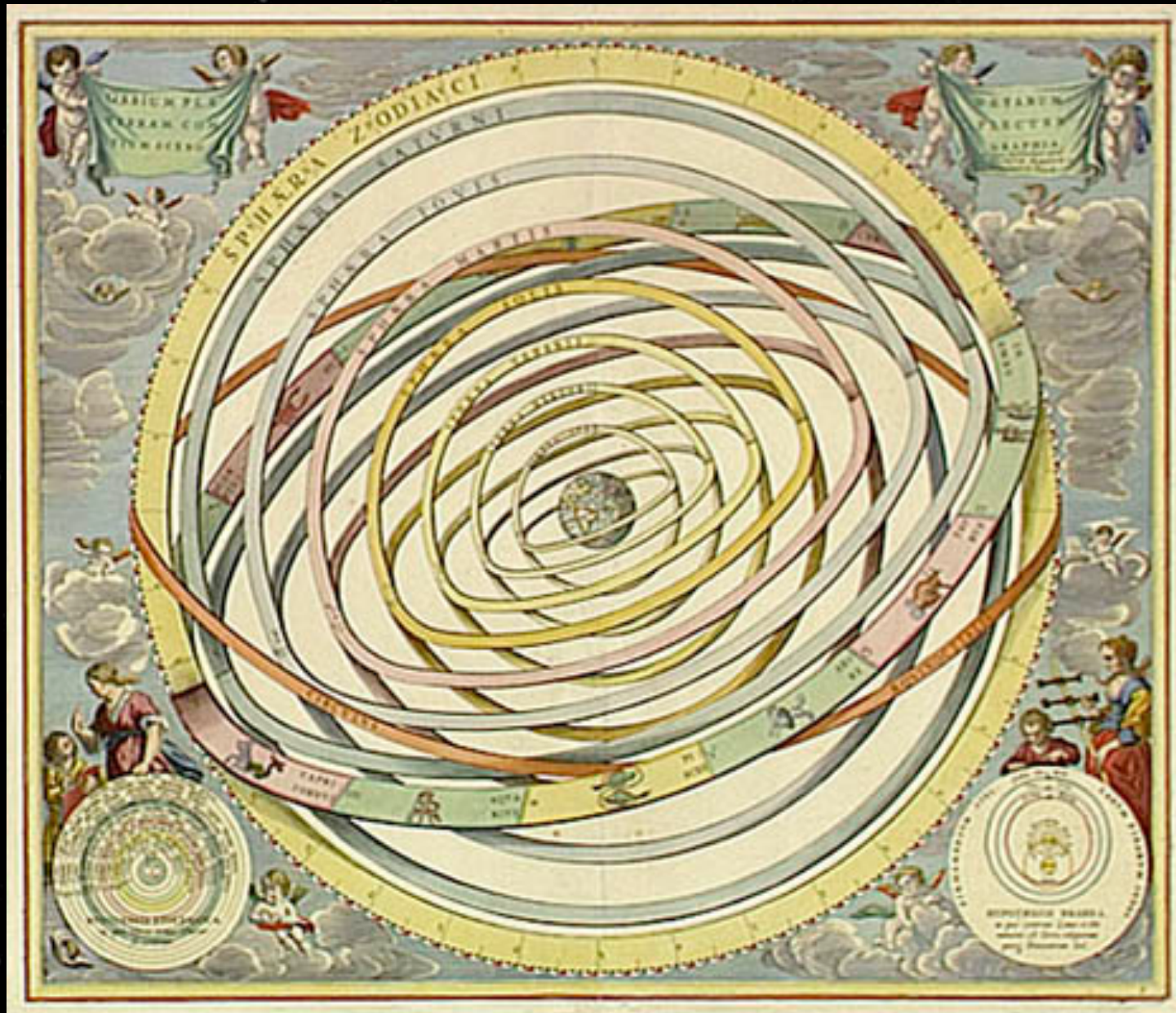
Galen-(Roman)-traditional theory of health and disease

- Believed in Hippocratic theory of four Humours: Phlegm-(head), blood-(heart), black bile-(liver), yellow bile-(gall bladder)
- Related to Head, Heart, Liver
- When one humour is out of balance- person becomes ill
- Example-if a person is too emotional-too much blood-need to bleed them
- *Bloodletting used until early 19th c as a cure*

Biology: The Circulation of Blood

- In biology, William Harvey (1578-1657) accurately demonstrated how blood circulates through the human body.
- Challenges old theories





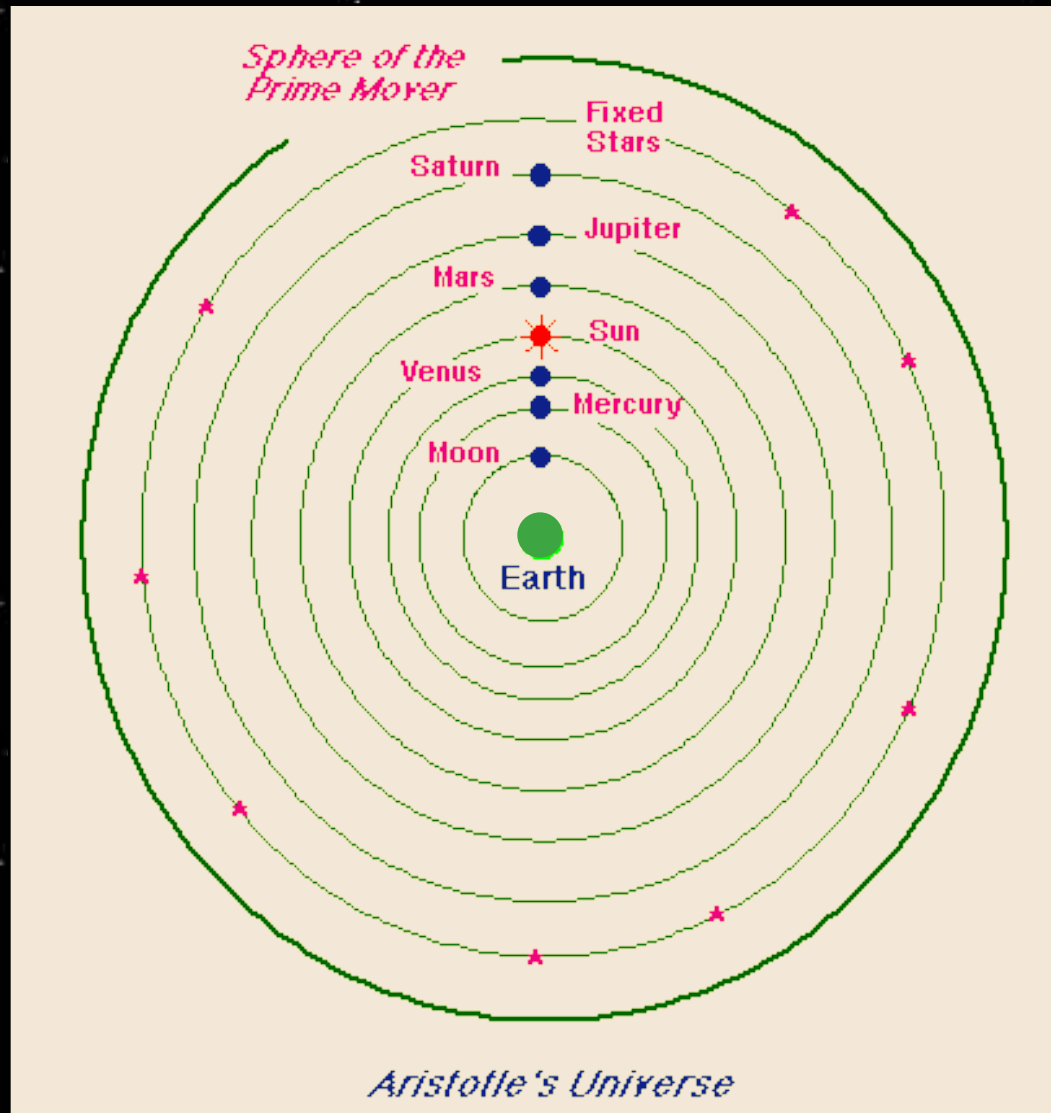
View of the Universe 500 Years Ago



Based on ancient speculations: "The School of the Athens" by Raphael (1510)⁹



Plato (c.428-347 BC), the idealist, points to sky and his World of Ideas (perfection)
Aristotle (384-322 BC), the realist, points to the ground (imperfection)



Aristotle's View of the Universe: 55 crystalline spheres, celestial objects attached to spheres, spheres rotated at different velocities, the Earth was at the center.¹

Three Guiding Principles

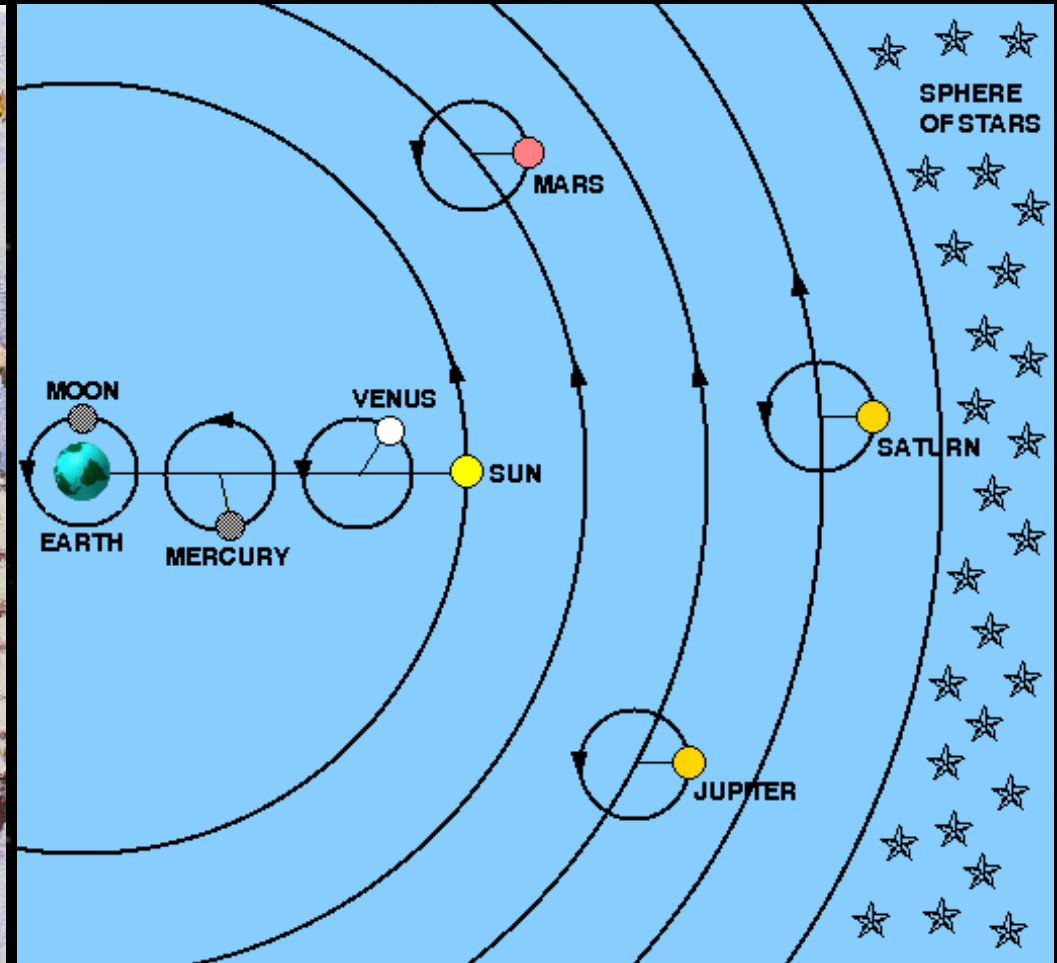
Earth is at the center of the Universe

All motion in the heavens is uniform circular motion

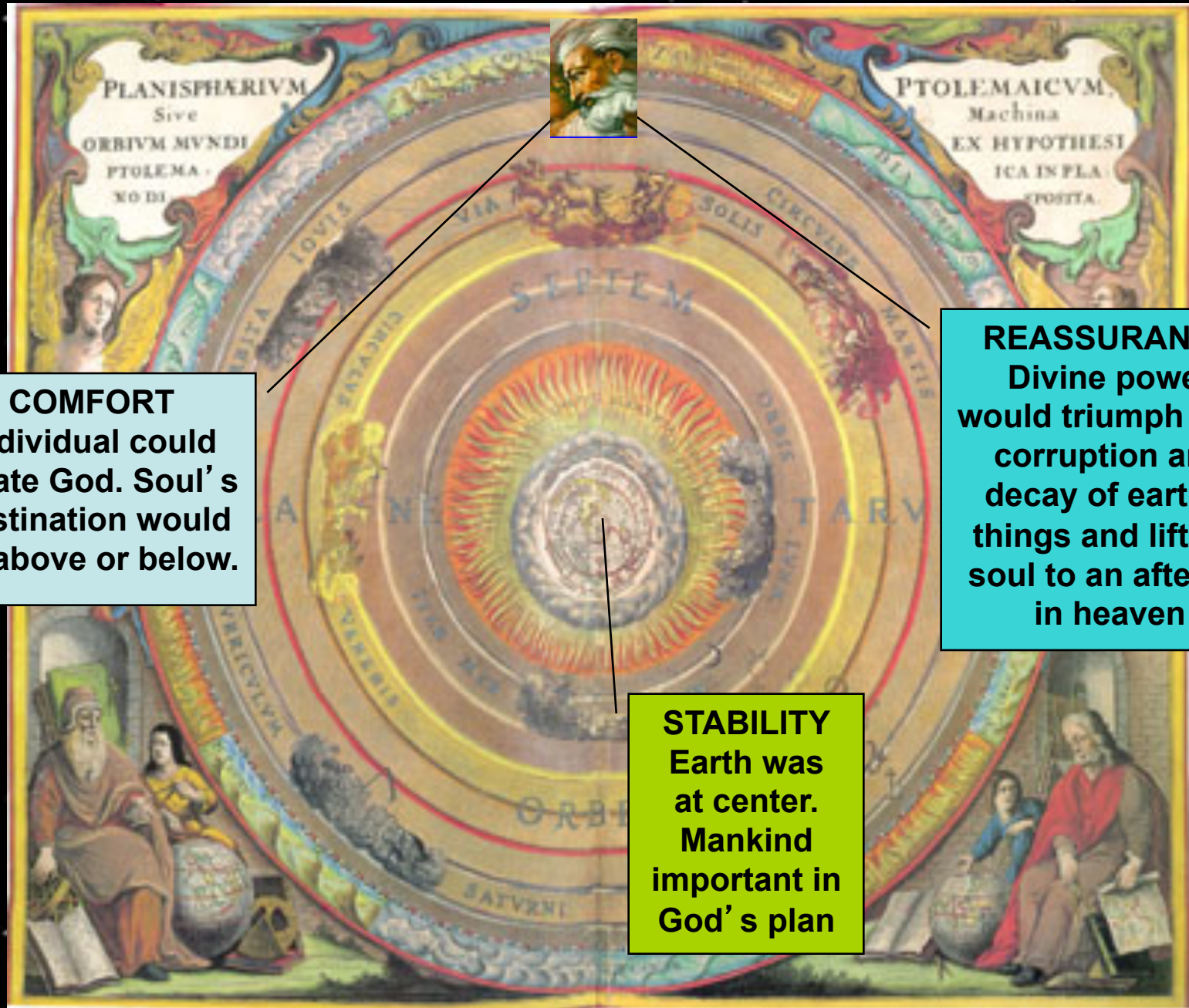
Celestial objects are made from perfect material and cannot change their properties (e.g., their brightness).



Aristotle's Prime Mover



The Ptolemaic Universe : Ideas about uniform circular motion and epicycles were catalogued by Ptolemy in 150 A.D. in his book the *Almagest*.



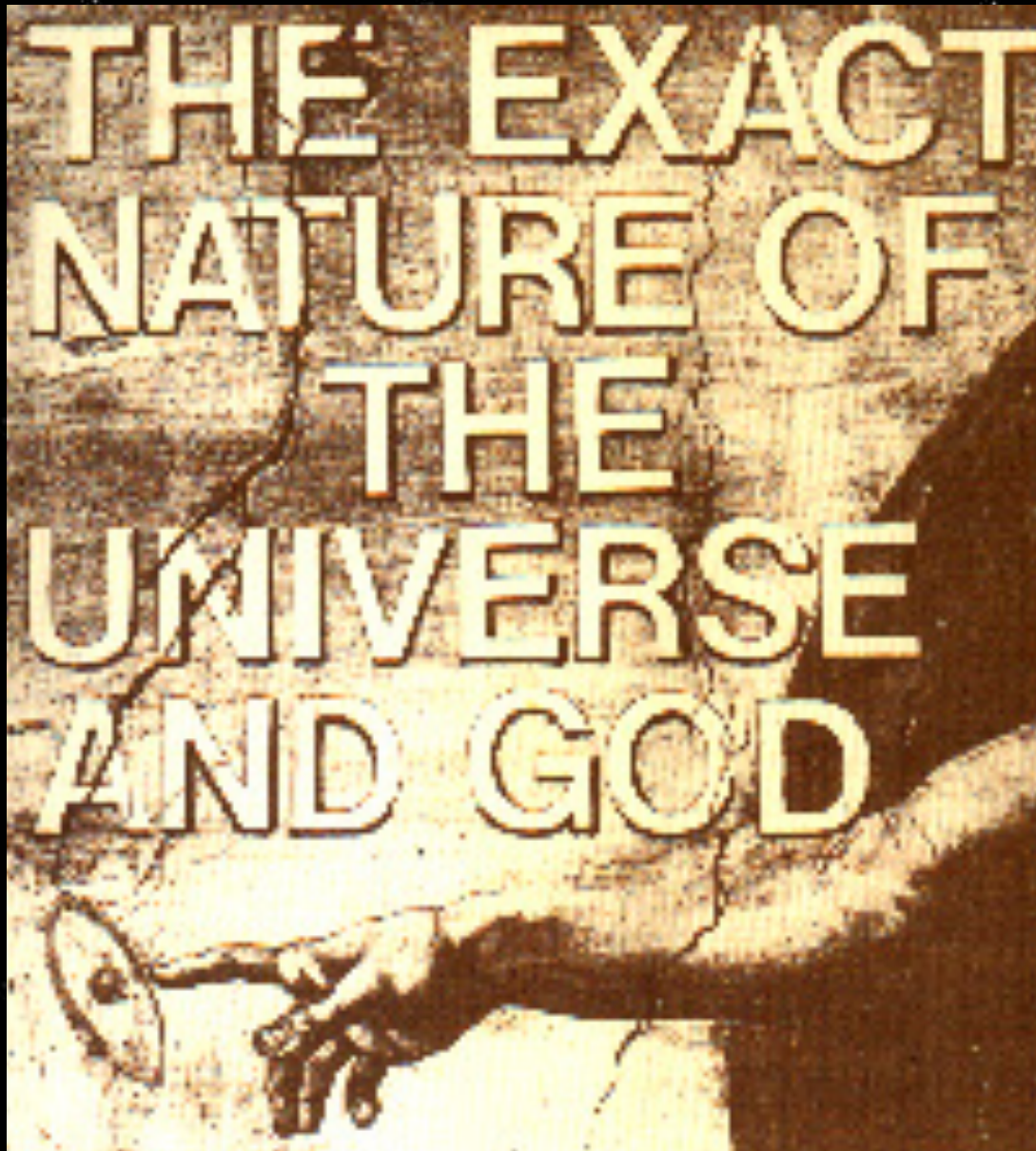
Medieval Representation of Ptolemaic Universe

**Aristotle's
Prime Mover
became the
God of
Christian
theology.**



**The outermost
sphere became
the Christian
heaven.**

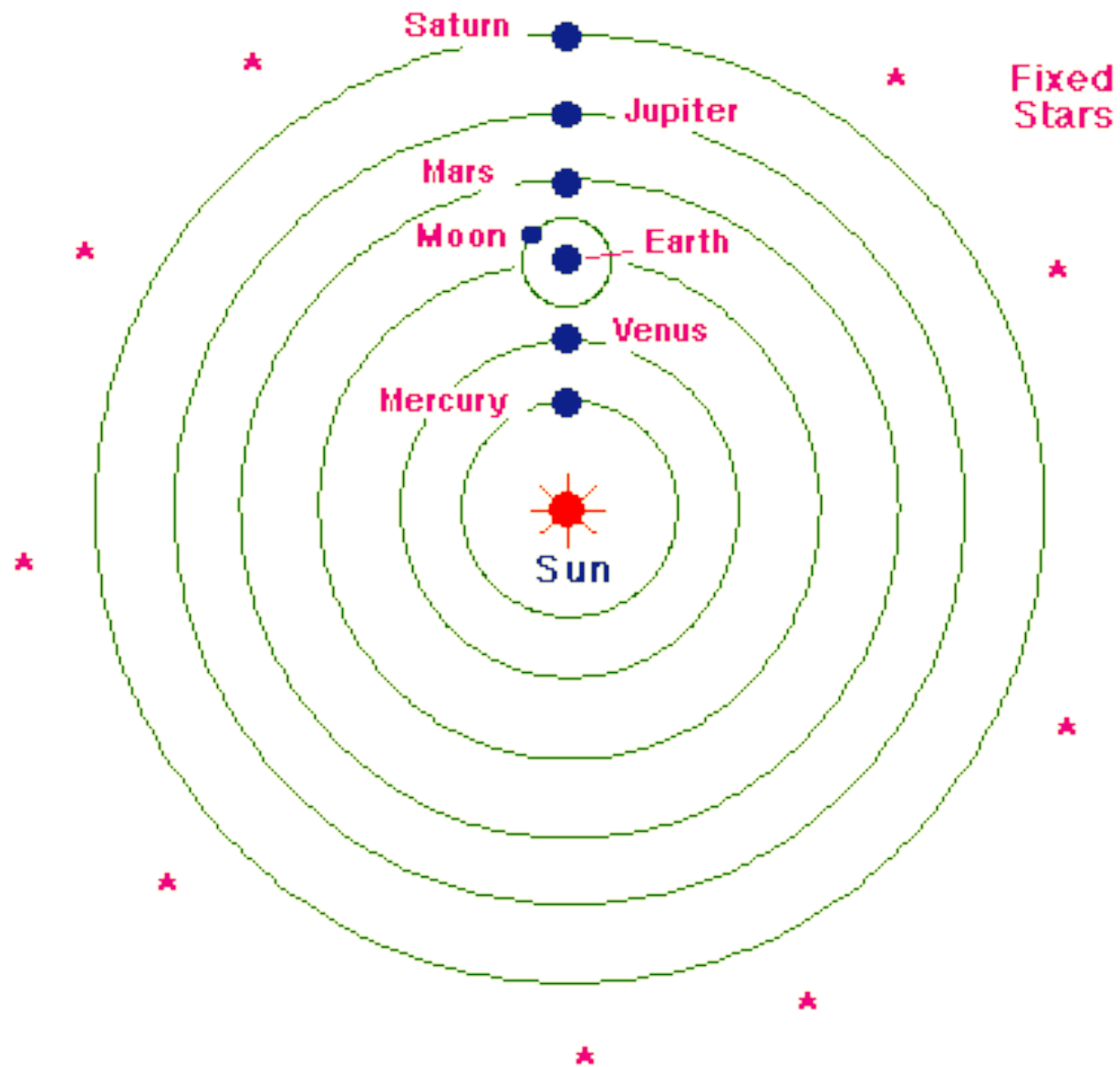
**Earth at center
represented the
Christian God's
concern for
mankind.**



Religious Dogma: Ideas originating with pagan Greek philosophers were incorporated into the Catholic church and became dogma. To challenge this view of the universe was to challenge, not only science, but theology.



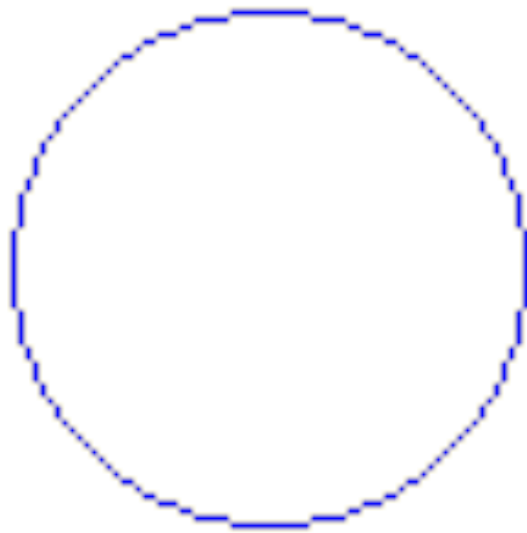
Finally, Polish astronomer Nicolas Copernicus (1473-1543) proposed a sun-centered solar system. Did he get into trouble? No, *On the Revolutions of the Heavenly Bodies* was published on his deathbed . 17



*Copernicus'
Universe*



Contemporary Representation of Copernicus' Solar System



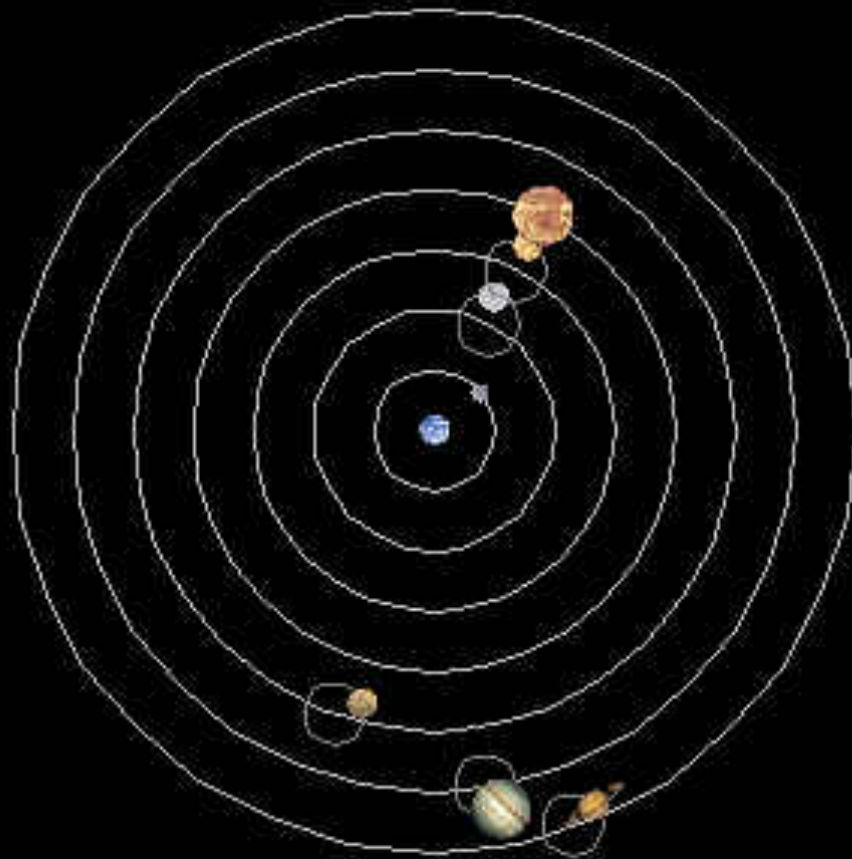
Circle



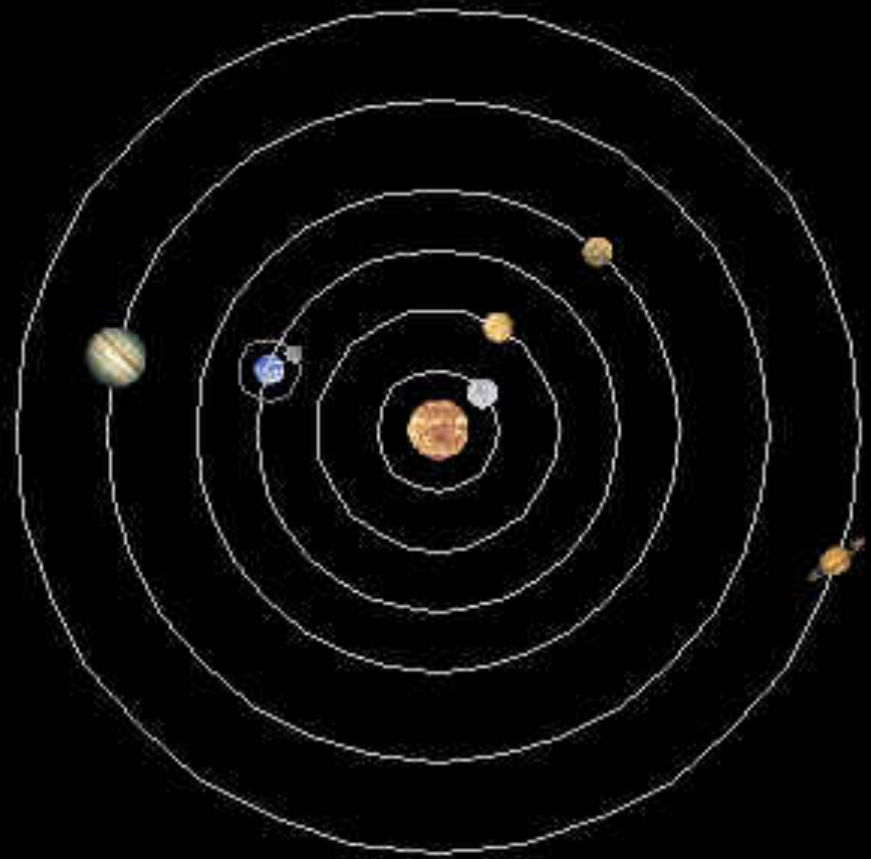
Ellipse

Since the orbits of the planets are not circles but ellipses, Copernicus could not explain all the details of planetary motion without epicycles 20

Geocentric Universe



Heliocentric Universe





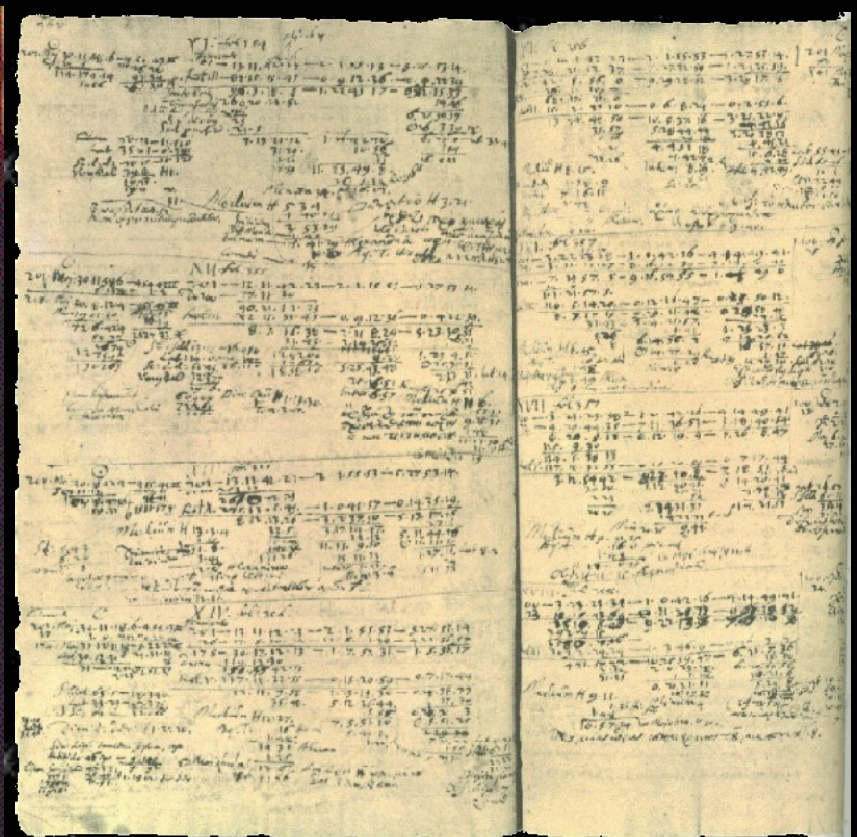
A Danish nobleman, Tycho Brahe (1546-1601), made important contributions: an astronomical observatory, precise instruments, extensive data on Mars²² (Kepler used to prove that the orbit of Mars was not a circle but an ellipse).



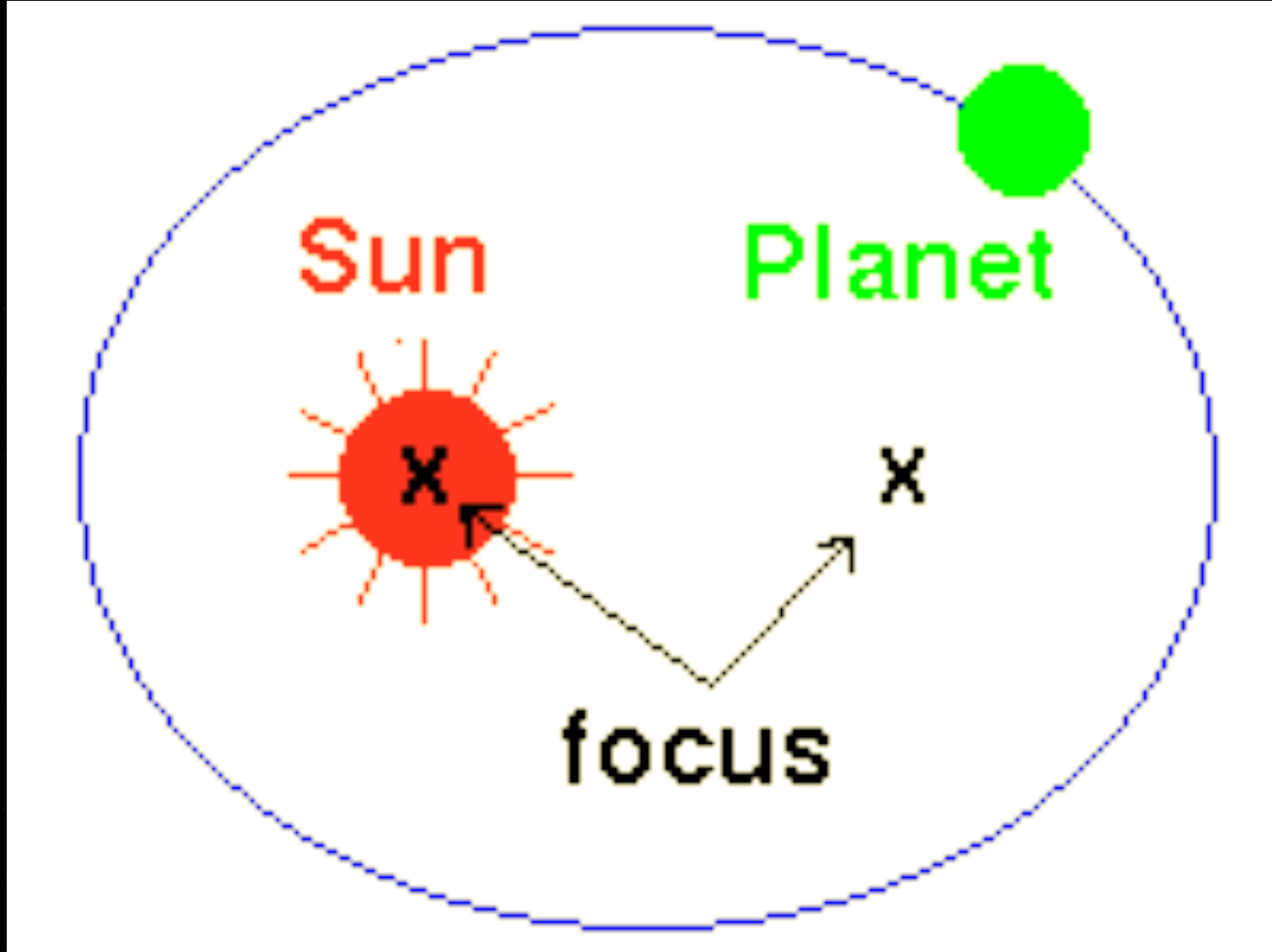
Brahe's Observations: Proposed a model intermediate between the Ptolemaic and Copernican models with Earth at center (widely accepted)



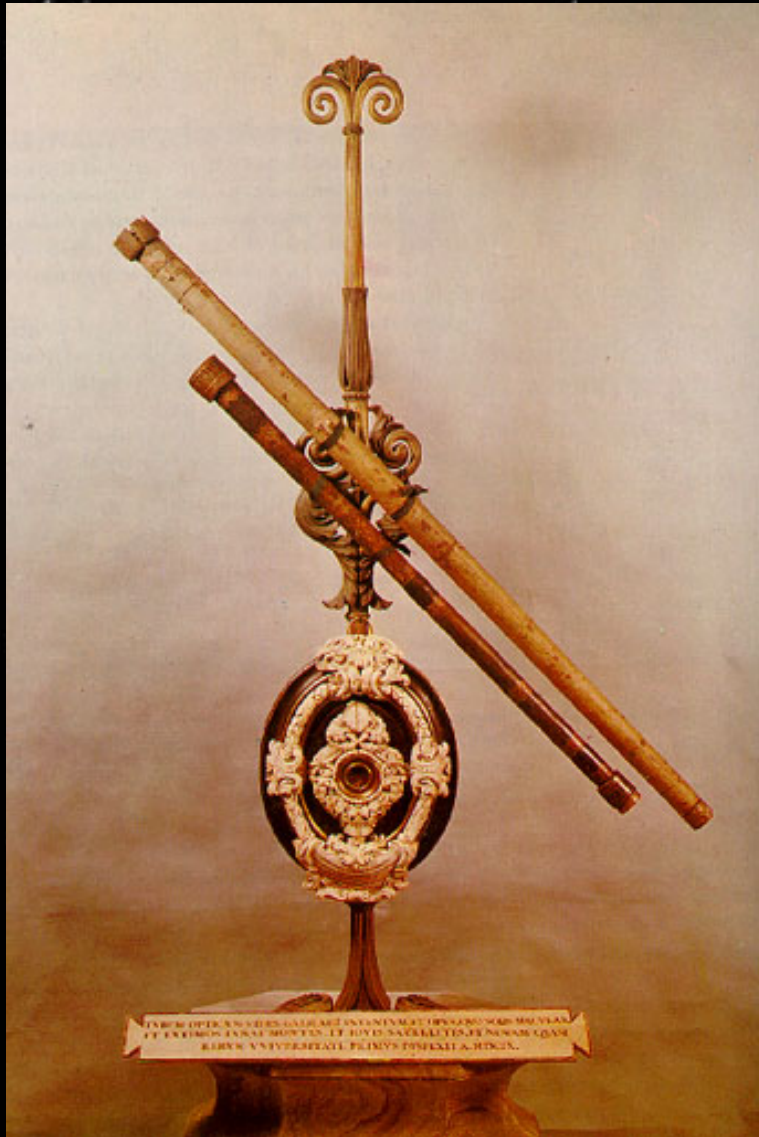
Brahe's Solar System



Johannes Kepler (1571-1630), a German who went to Prague to become Brahe's assistant, realized that the orbits of the planets were not circles but ellipses and developed three laws to describe the phenomenon he observed.



Kepler's First Law: The orbits of the planets are ellipses, with the Sun at one focus of the ellipse.

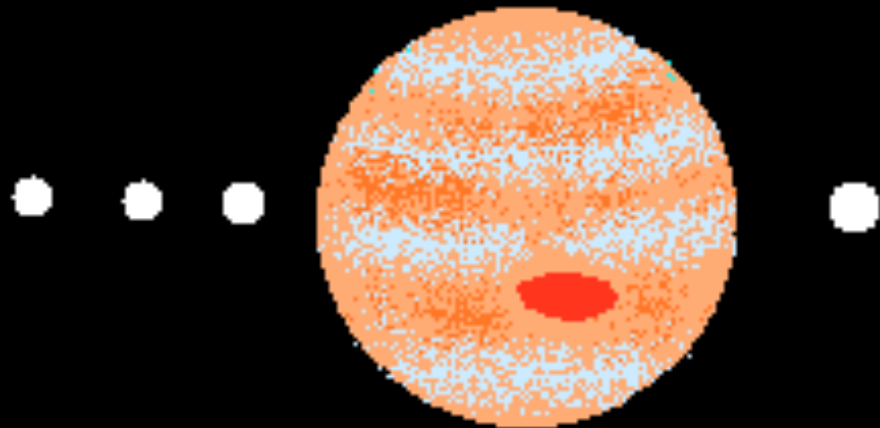


Galileo Galilei (1564-1642) proved the Copernican theory with his telescope, challenged Aristotle's universe and its theological-philosophical worldview, and laid the foundations for dynamics (how objects move on the earth) and gravity.



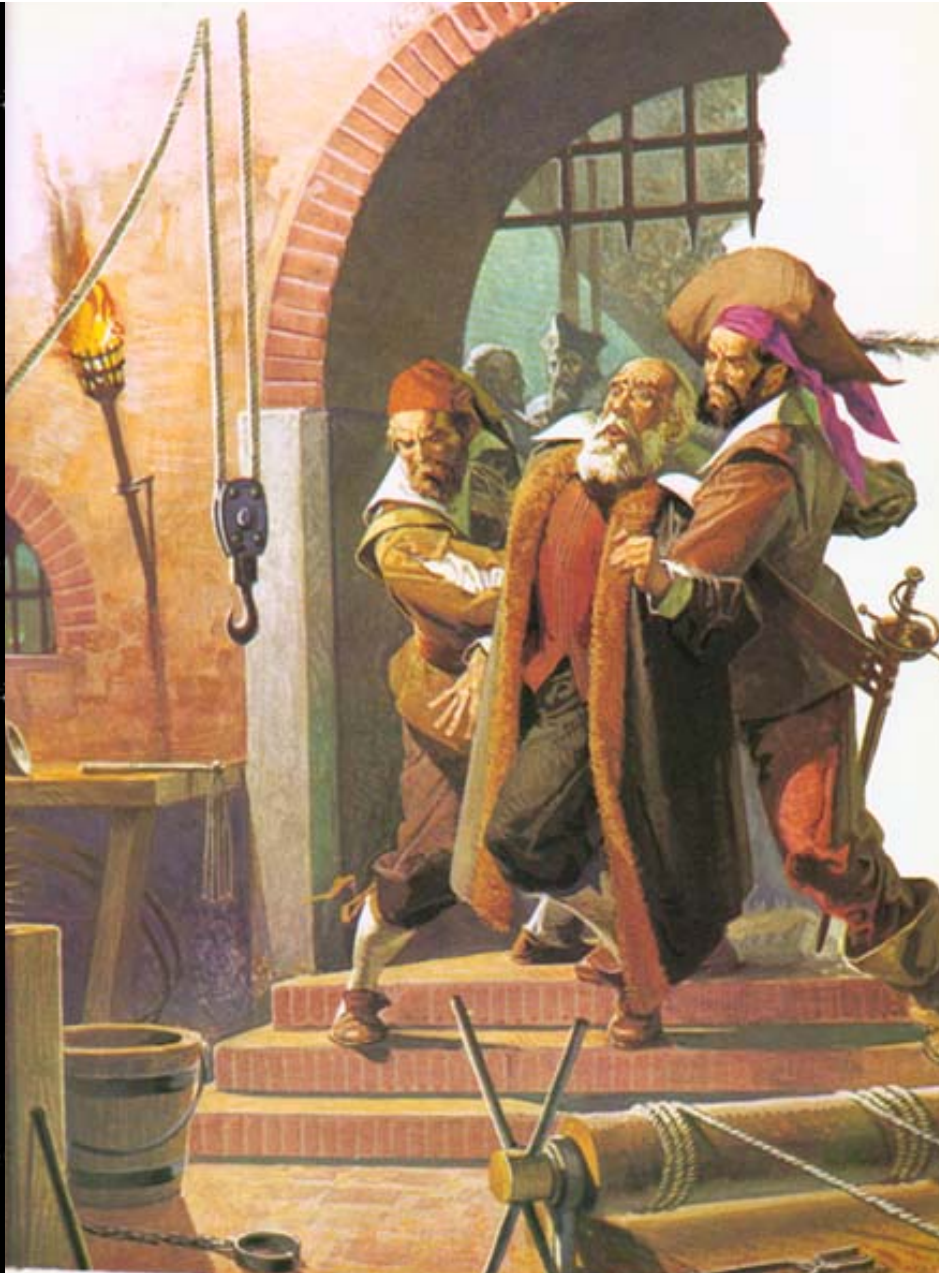
Sunspots

Galileo observed sunspots that moved, indicating that the Sun was rotating on an axis and that it was not made from a perfect, unchanging substance.



Galilean Moons of Jupiter

He observed four points of light that changed their positions around the planet Jupiter and concluded that they were moons circling the planet as it moved around its orbit.



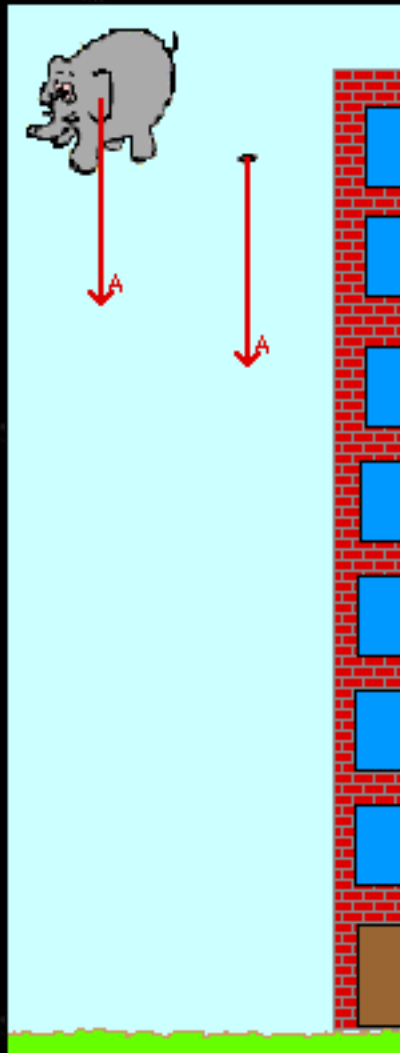
Galileo's challenge of the Church's authority got him into deep trouble with the Inquisition. Late in his life, he was forced to recant his Copernican views publicly.



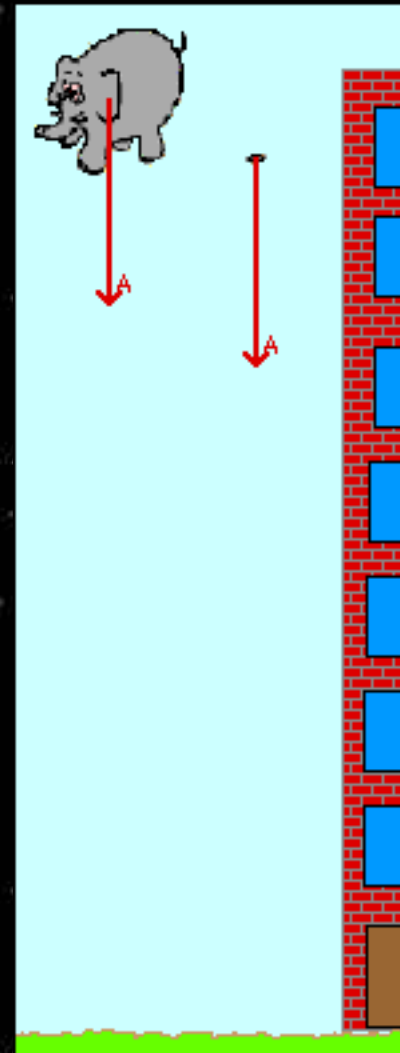
Sir Isaac Newton (1642-1727) Newton demonstrated that the motion of objects on the Earth could be described by three new Laws of Motion and the Universal Law of Gravitation. 30



Newton's First Law of Motion: An object in motion tends to stay in motion and an object at rest tends to stay at rest, unless the object is acted upon by an outside force

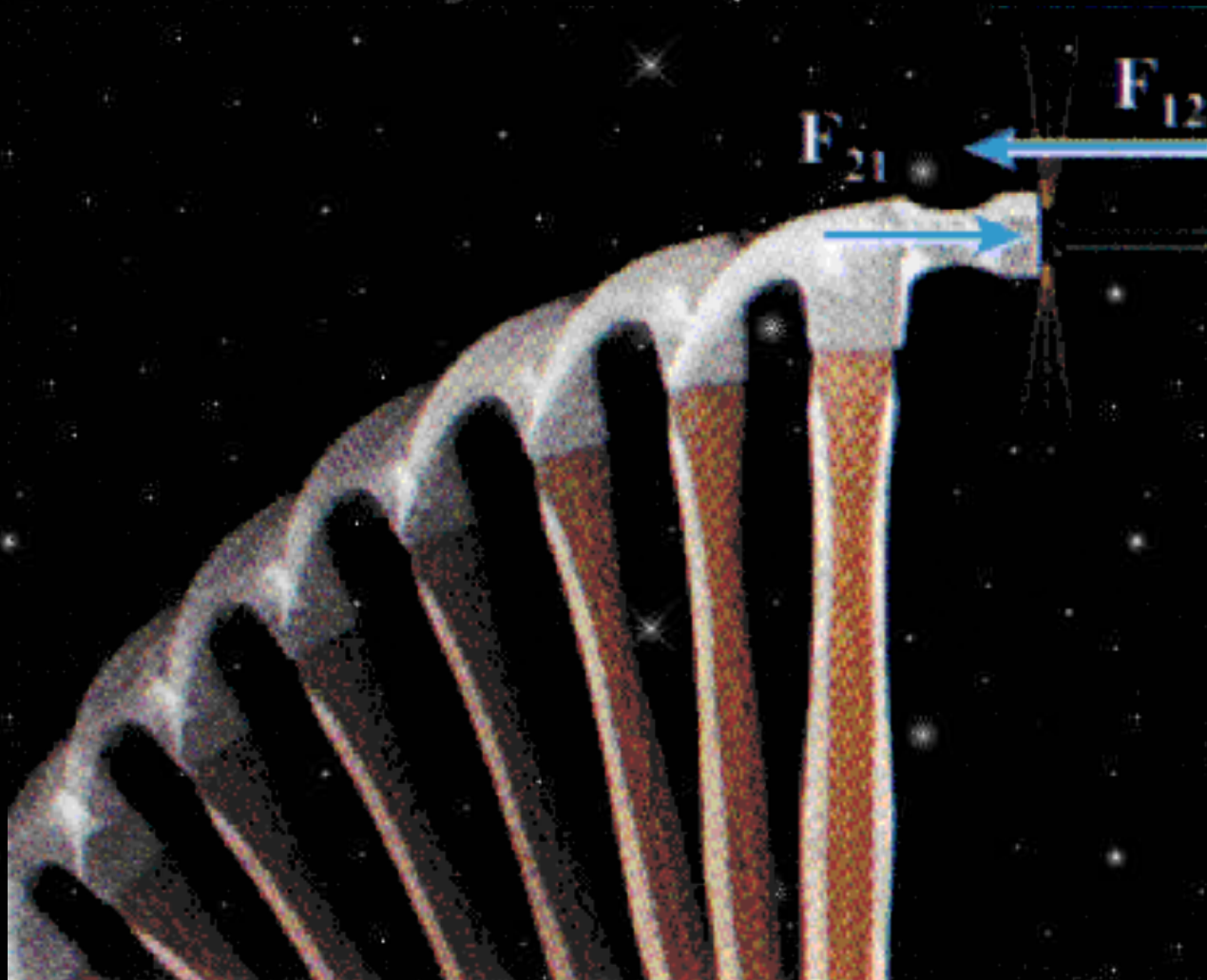


Free Fall



Air Resistance

Newton's Second Law of Motion: The acceleration of an object is directly proportional to the net force acting upon it and inversely proportional to its mass.



Newton's Third Law of Motion: Every action has an equal and opposite³³ reaction.



When he observed an apple fall from a tree, Newton thought: The apple is accelerated as it moves from the tree toward the ground. There must be a force that acts on the apple to cause this acceleration. Let's call the force gravity. If the force of gravity reaches to the top of the highest tree, might it not reach even further to the orbit of the Moon. Then, the orbit of the Moon about the Earth could be a consequence of the gravitational force.

Newton's Excellent Idea

- Now came Newton's truly brilliant insight: if the force of gravity reaches to the top of the highest tree, might it not reach even further to the orbit of the Moon. Then, the orbit of the Moon about the Earth could be a consequence of the gravitational force.

Law of Universal Gravitation

Every object in the Universe attracts every other object with a force directed along the line of centers for the two objects that is proportional to the product of their masses and inversely proportional to the square of the separation between the two objects.

$$F_g = G \frac{m_1 m_2}{r^2}$$

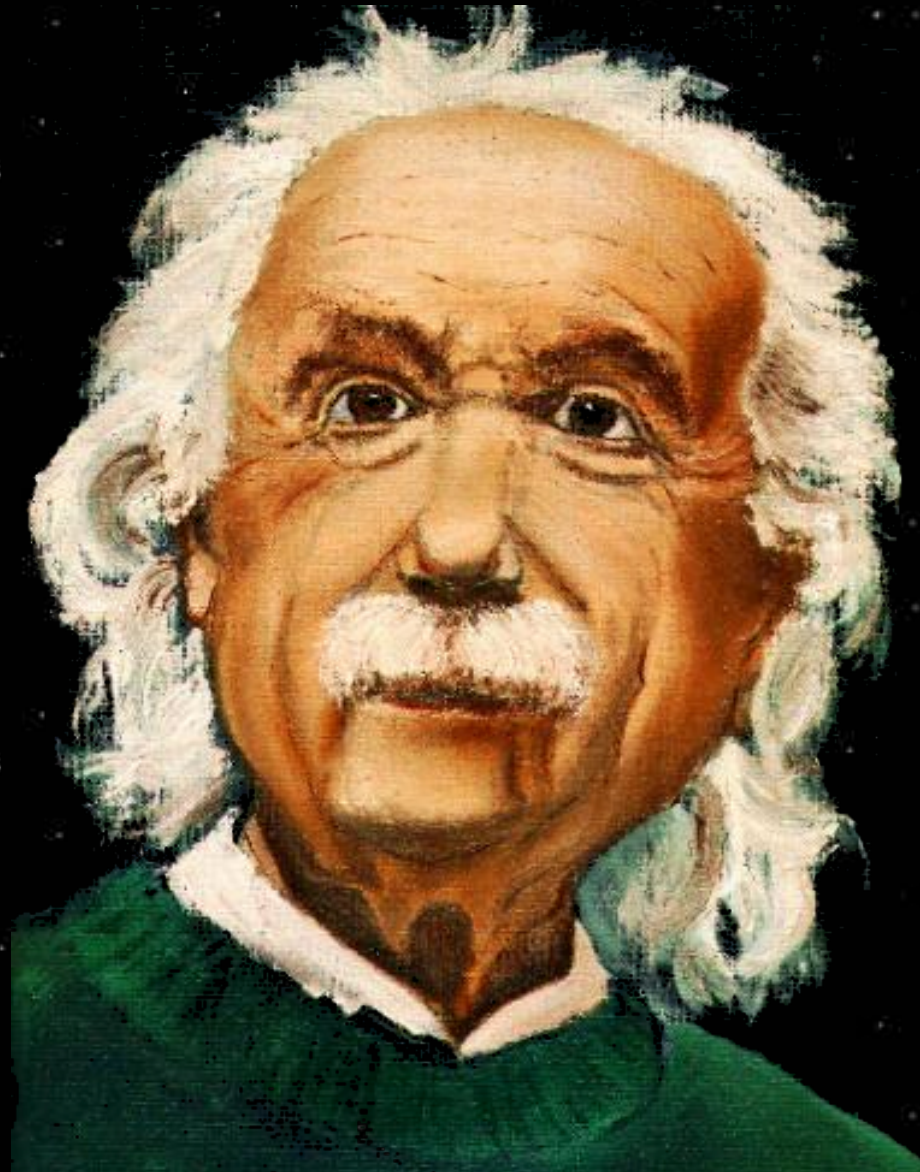


F_g is the gravitational force

m_1 & m_2 are the masses of the two objects

r is the separation between the points

G is the universal gravitational constant



Newton's theory of gravitation was soon accepted without question, and it remained unquestioned until the beginning of this century when Albert Einstein (1879-1955) shook the foundations of physics with the introduction of his Special Theory of Relativity (1905) General Theory of Relativity (1915).

Sir Francis Bacon: England-1561-1626



Francis Bacon-1561-1626

- Collection and analysis of data
- Was an English philosopher, statesman, scientist, jurist, orator, essayist and author
- Bacon has been called the father of empiricism.
- His works established and popularised inductive methodologies for scientific inquiry, often called the *Baconian method*, or simply the *scientific method*.

Empiricism

- **Theory that all knowledge is derived from sense-experience**
- **All concepts originate in experience**

Francis Bacon

- In order to test potential truths, or hypotheses, Bacon devised a method whereby scientists set up experiments to manipulate nature, and attempt to prove their hypotheses wrong.
- In short-Testing of scientific hypotheses.

RENE DESCARTES



RENE DESCARTES-

France-1596-1650

- Mathematician, scientist, and philosopher
- He promoted the development of a new science grounded in observation and experiment, he has been called the father of modern philosophy.
- ***“I think-therefore I am”***
- Inductive (reasoning from observations) and deductive reasoning (a conclusion must follow from a set of premises or hypotheses.)

Effects of the Scientific Revolution

- **Skepticism and Independent Reasoning:** For example, Descartes reached the extreme of skepticism by doubting his own existence. Then, he realized that his own act of thinking proved his own existence (I think, therefore, I am.)
- **Challenges to Religion:** The idea that the universe worked like a machine according to natural laws and without the intervention of God challenged established religious ideas. This position was adopted by the Deists in the 18th century.
- **Decline in Belief in Magic, Demons, and Witchcraft:** By the 18th century, the educated classes denied the existence of demons and the power of witchcraft. The skeptical views of the educated classes were not shared by the common people for whom religion remained important. The result was a divide between learned and popular culture.

Effects of the Scientific Revolution

- **Questions about Humanity's Role in the Universe:** By making humans the inhabitants of a tiny planet circling the sun, the Copernican Universe reduced the importance of humanity. It led people to begin to question the place of humanity in creation.
- **Gave Humanity Control of Nature:** Some philosophers argued that by gaining knowledge of the laws of nature, people could control nature. Through science and technology, they could improve human life. This belief in progress became an integral part of Western culture.
- **Challenges to Established Views of Women:** The new scientific ideas challenged the ancient and medieval beliefs about the physical and mental inferiority of women by concluding that both men and women made equal contribution to reproduction. Nevertheless, traditional notions about women continued to dominate